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Cross Section Measurements at LANSCE for Defense, Science and Applications

R. O. Nelson

LANSCE-NS

Los Alamos National Laboratory

International Conference on

Nuclear Data for Science and Technology

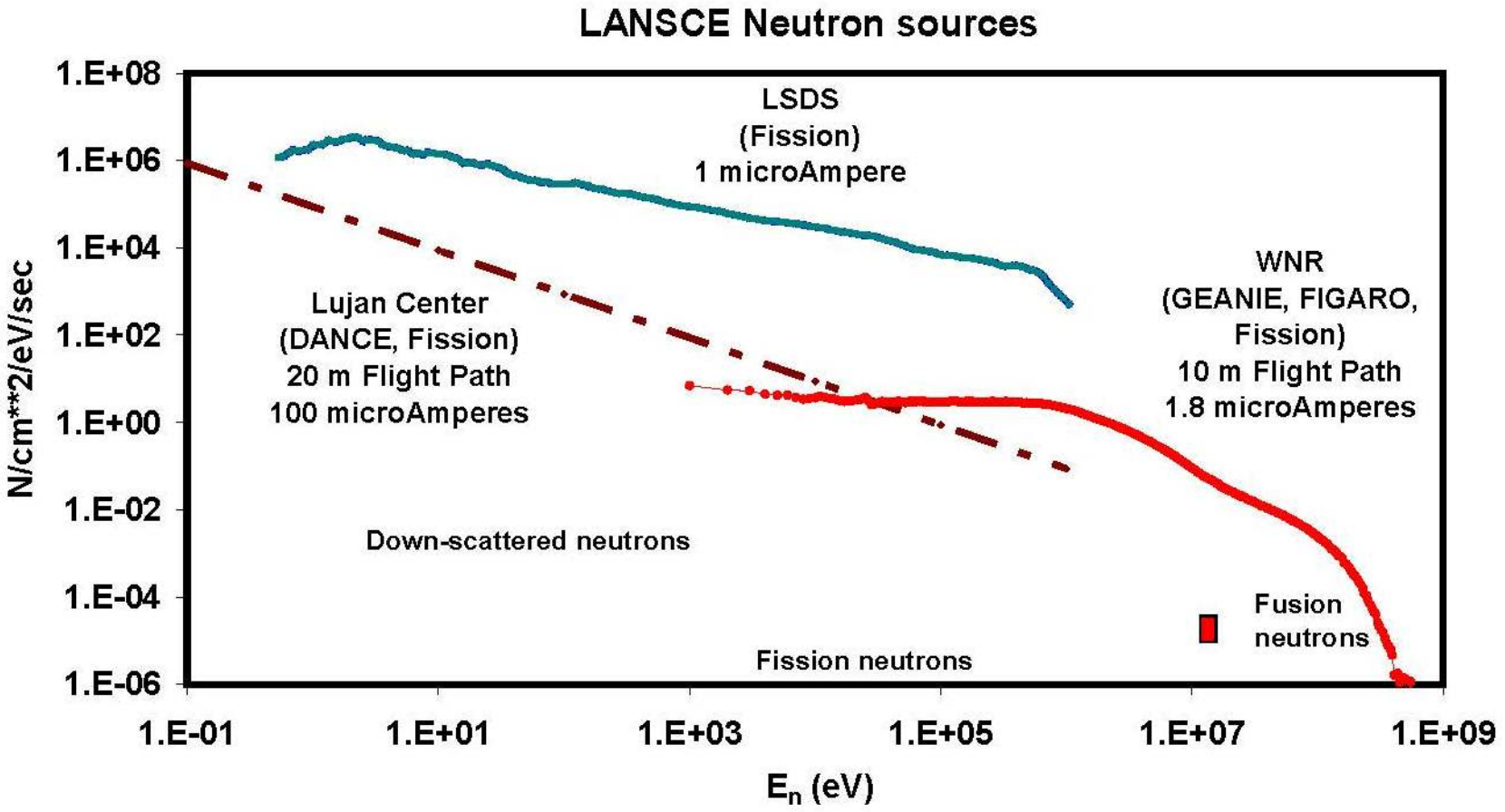
Dresden, Germany

25-29 August, 2014

Outline

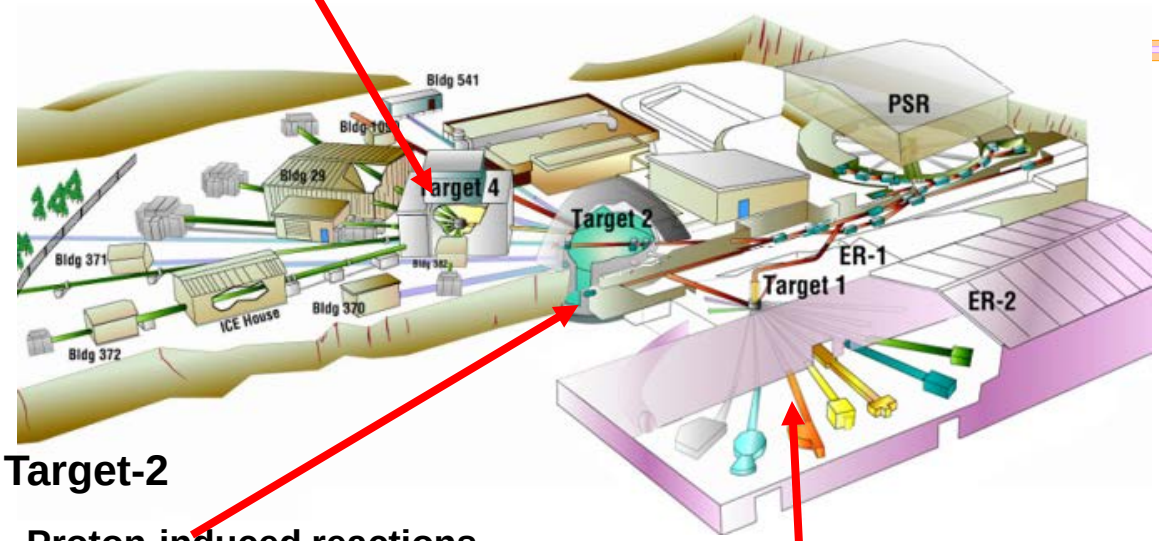
- LANSCE
- Facilities
  - New RF Driver (201 MHz)
- User program
  - Changes to User Program for Material Science
  - Nuclear Science User Program continues
- Cross section measurements
  - GEANIE data and model development
    - » Reference cross sections
  - Chi-Nu and inelastic measurements
  - Fission cross sections – TPC, SPIDER
  - Total cross sections for neutron capture cross sections
- Summary

LANSCE Neutron Sources Cover Energies for Most Applications



Nuclear Science research is performed at many experimental areas at LANSCE

Target-4
High-energy neutron research

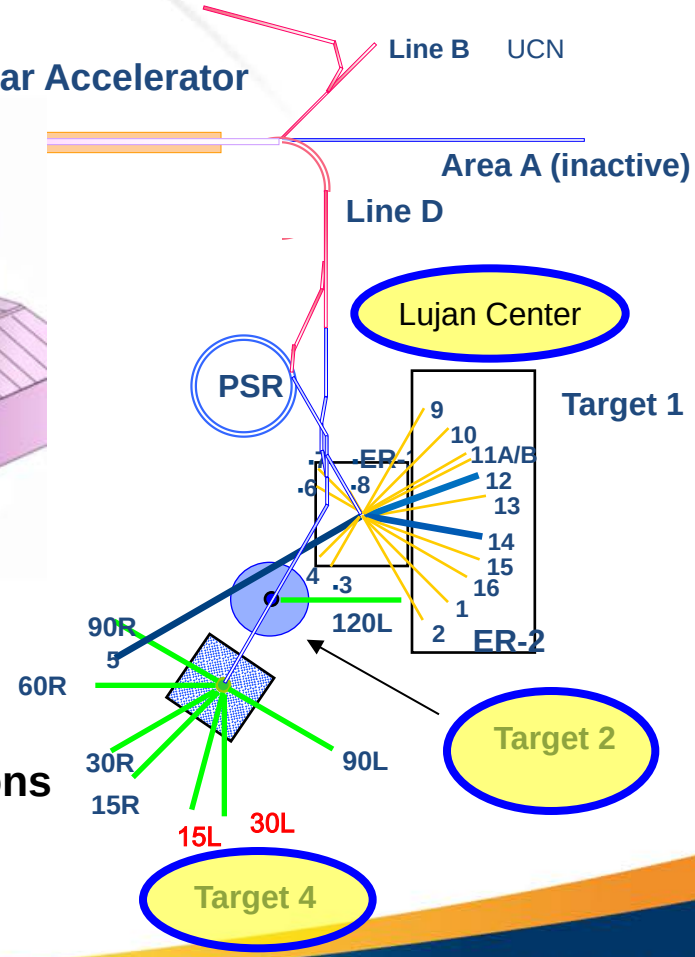


Target-2

- Proton-induced reactions
  Single-pulse experiments (Sandia)
  Lead Slowing-Down Spectrometer
  SNS target testing
  Isotope production testing
  99Mo production tests

Lujan Center

Low-energy neutrons
- Material science
- Nuclear science

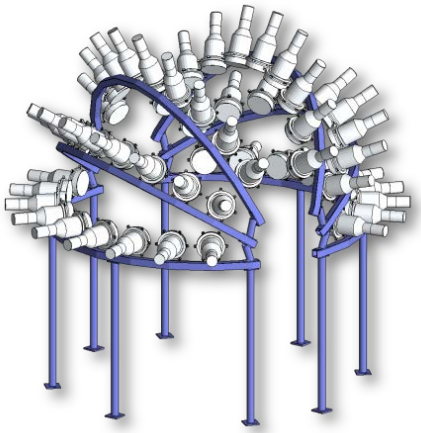


Many Instruments have been developed for nuclear science measurements at LANSCE

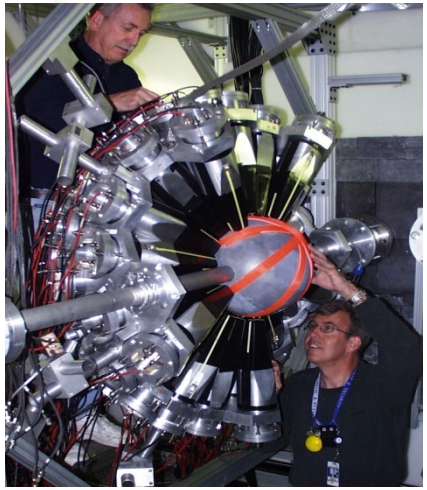
Los Alamos NATIONAL LABORATORY EST. 1943

GEANIE (n,xγ)

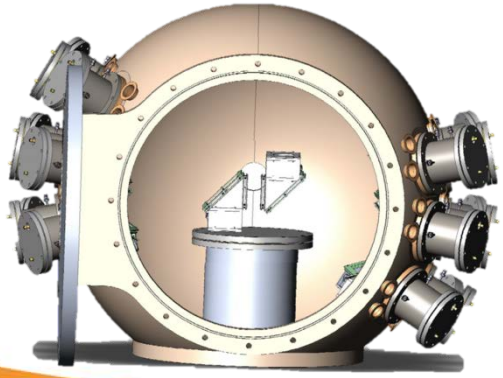
Chi Nu (n,xn+γ)



DANCE (n,γ)



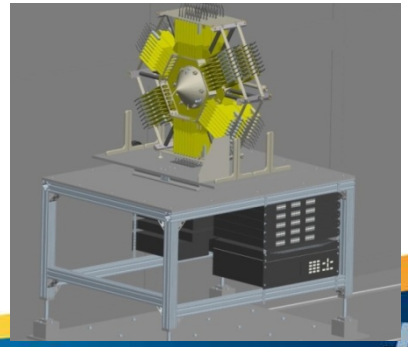
SPIDER



Fission

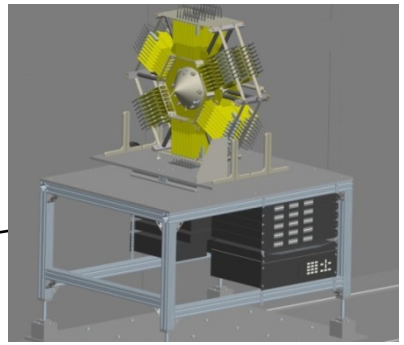
LSDS

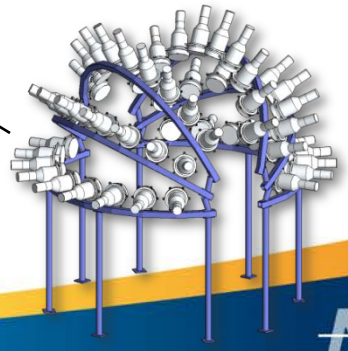
TPC

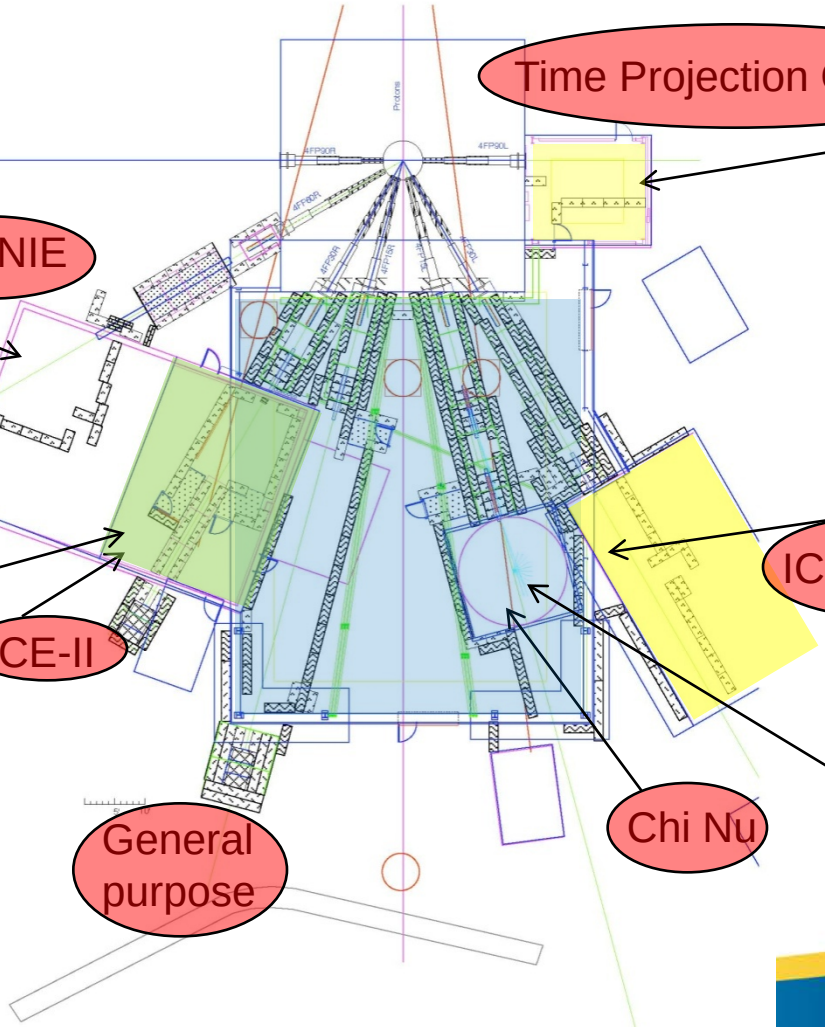


NNSA National Nuclear Security Administration

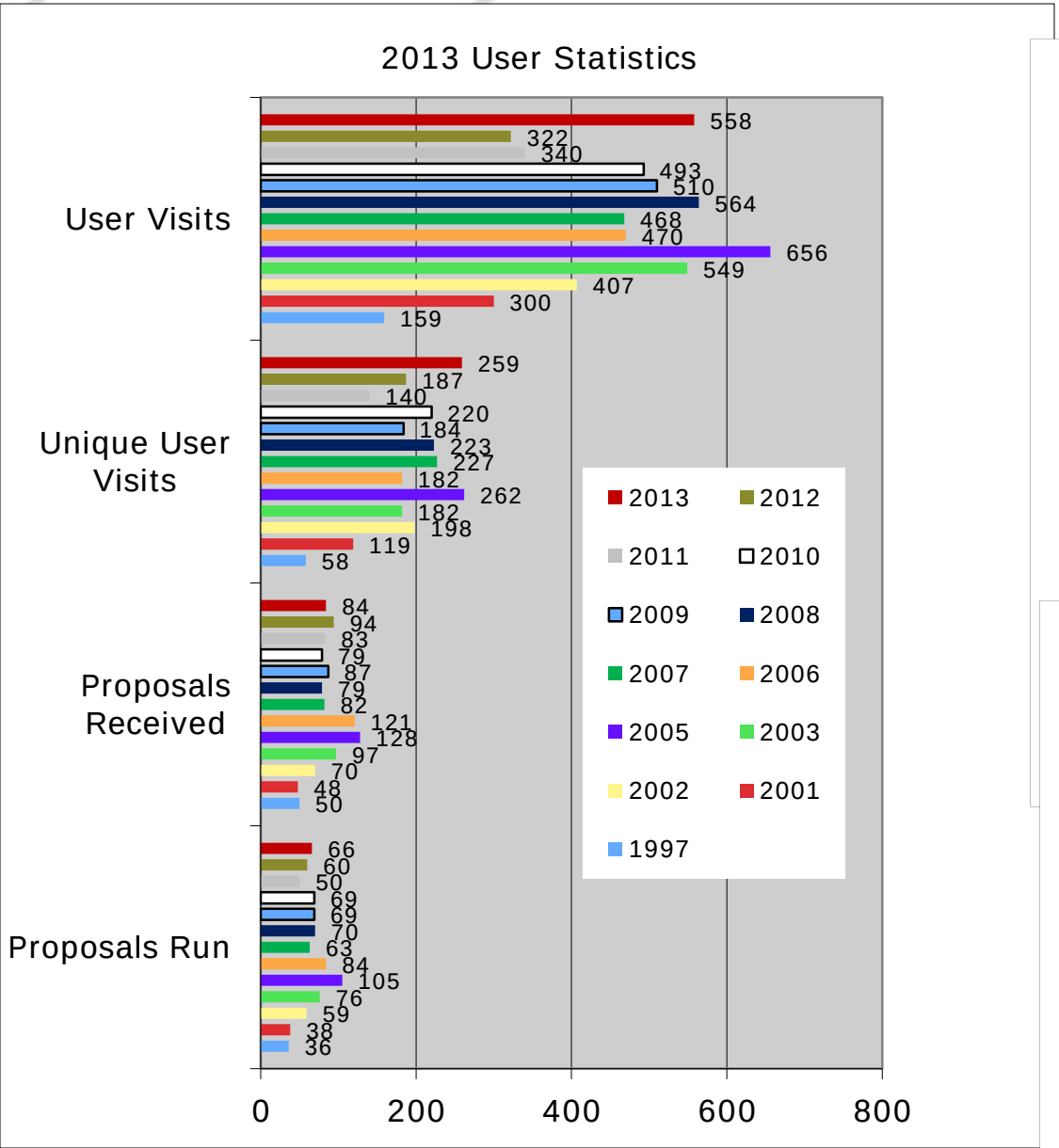
Neutron Flight Paths at LANSCE/WNR

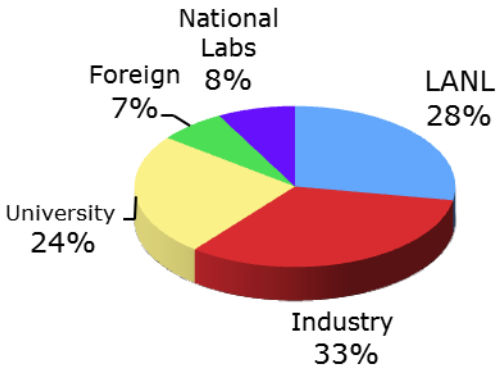


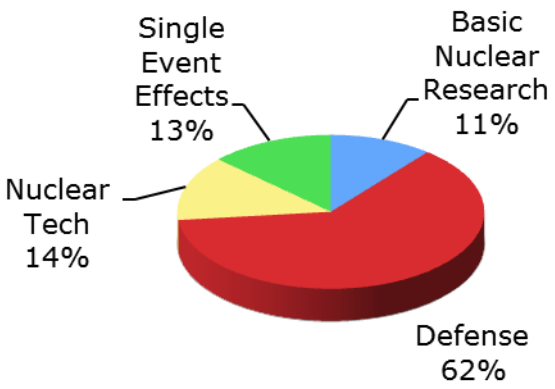




Nuclear Science User Statistics



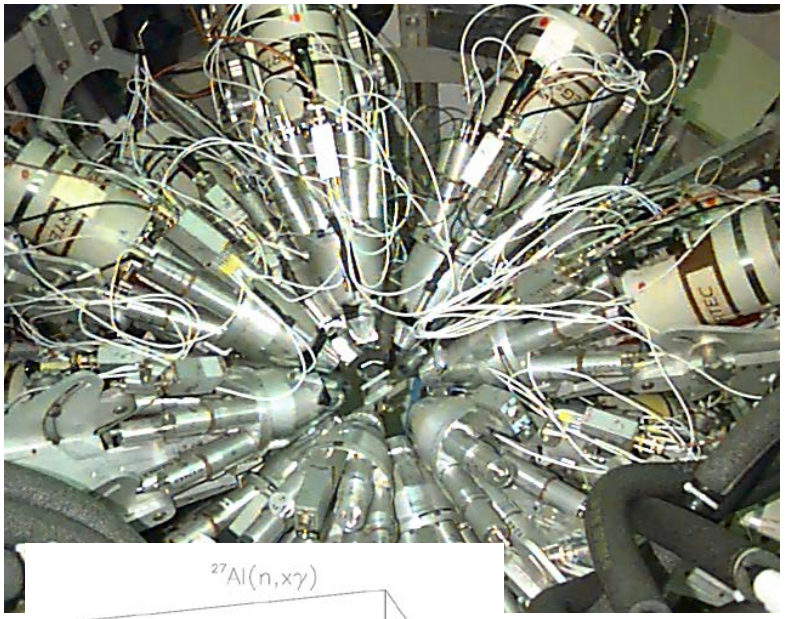


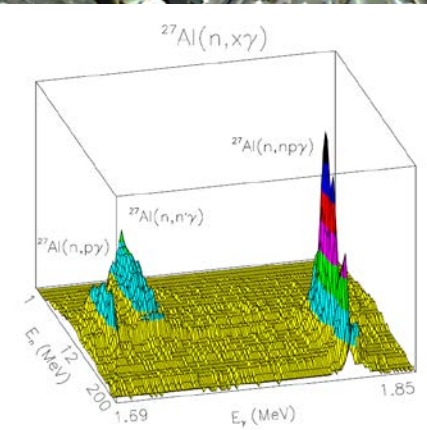


GEANIE at LANSCE/WNR Provides High-Resolution (n,xnypz$\alpha\gamma$) Data Over a Wide Neutron Energy Range

- **Combination of planar Ge (x-ray and γ) detectors and coaxial Ge detectors – 26 total**
- **Photon energy range 15 keV < E_γ < 9 MeV**
- **BGO background suppression shields**
- **Measure gamma-ray pulse height, neutron time of flight, 100 keV < E_n < 400 MeV**
- **Built using elements of the former HERA array from LBL**
- **Collaboration with LLNL and CEA Bruyères-le-Châtel**

GEANIE γ-ray Spectrometer Array





GEANIE
LLNL/LANL

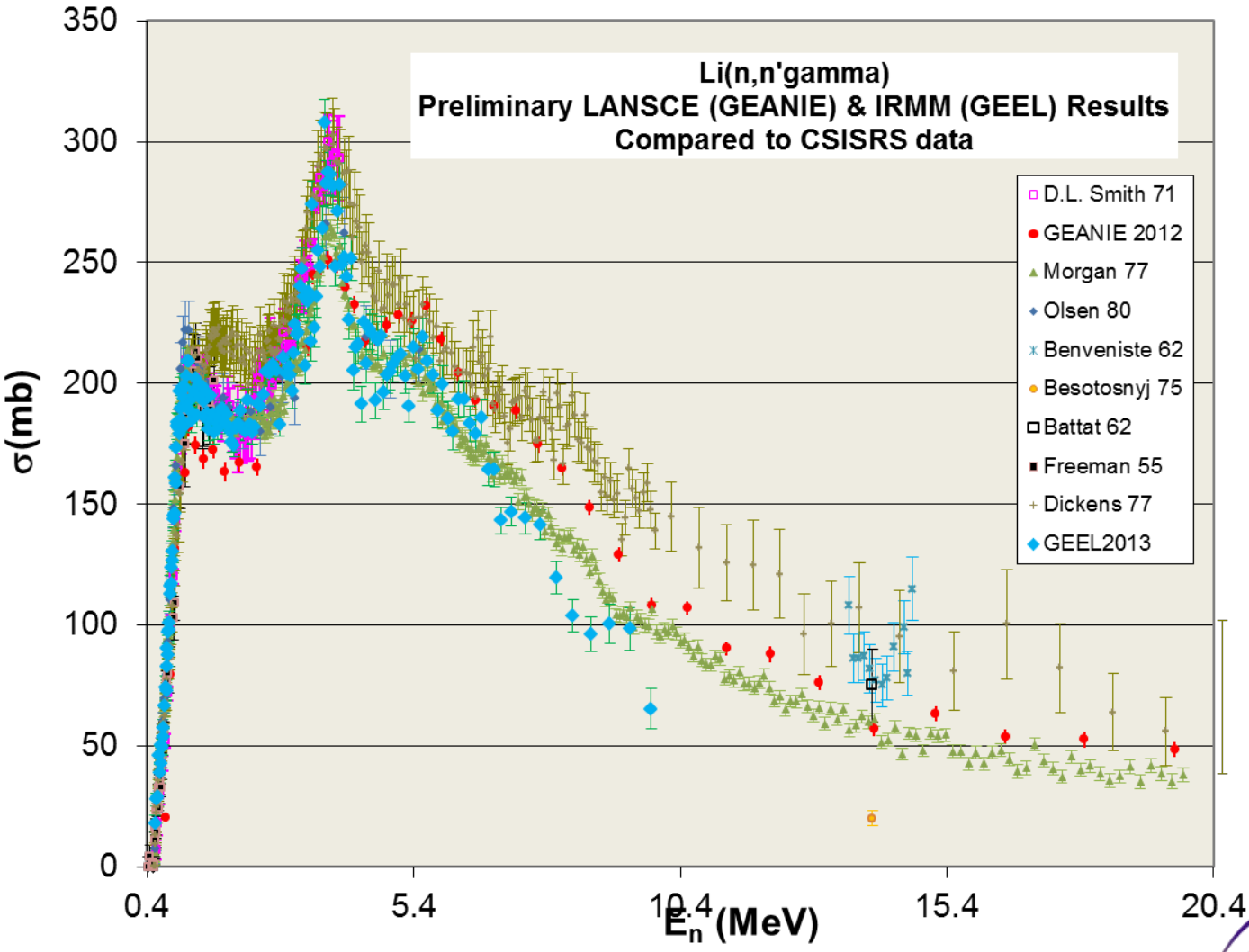
The Search for More Suitable γ-Ray Cross Section Reference Candidates

- **Several candidate samples were measured, but rejected for a variety of reasons**
  - **Nb – previously unknown isomers**
  - **In – previously unknown isomers**
  - **Au – isomers, nearby background lines**
  - **V – activation by (n,p), angular anisotropy, low Eγ**
- **Ti – similar to Fe, with some advantages**
  - **Less contribution from (n,p) activation**
  - **Excellent physical properties**
  - **Large cross section and 74% ^{48}Ti**
- **Li showed promise – LiF proved to have suitable properties**
  - **Available as LiF optical windows**
  - **Not hygroscopic**
  - **Chemically pure, especially UV windows (92.4% ^{7}Li)**
  - **Fluorine - strong gammas (110 & 197 keV) may be useful**

Properties of Li, and Ti for Reference Cross Section Use

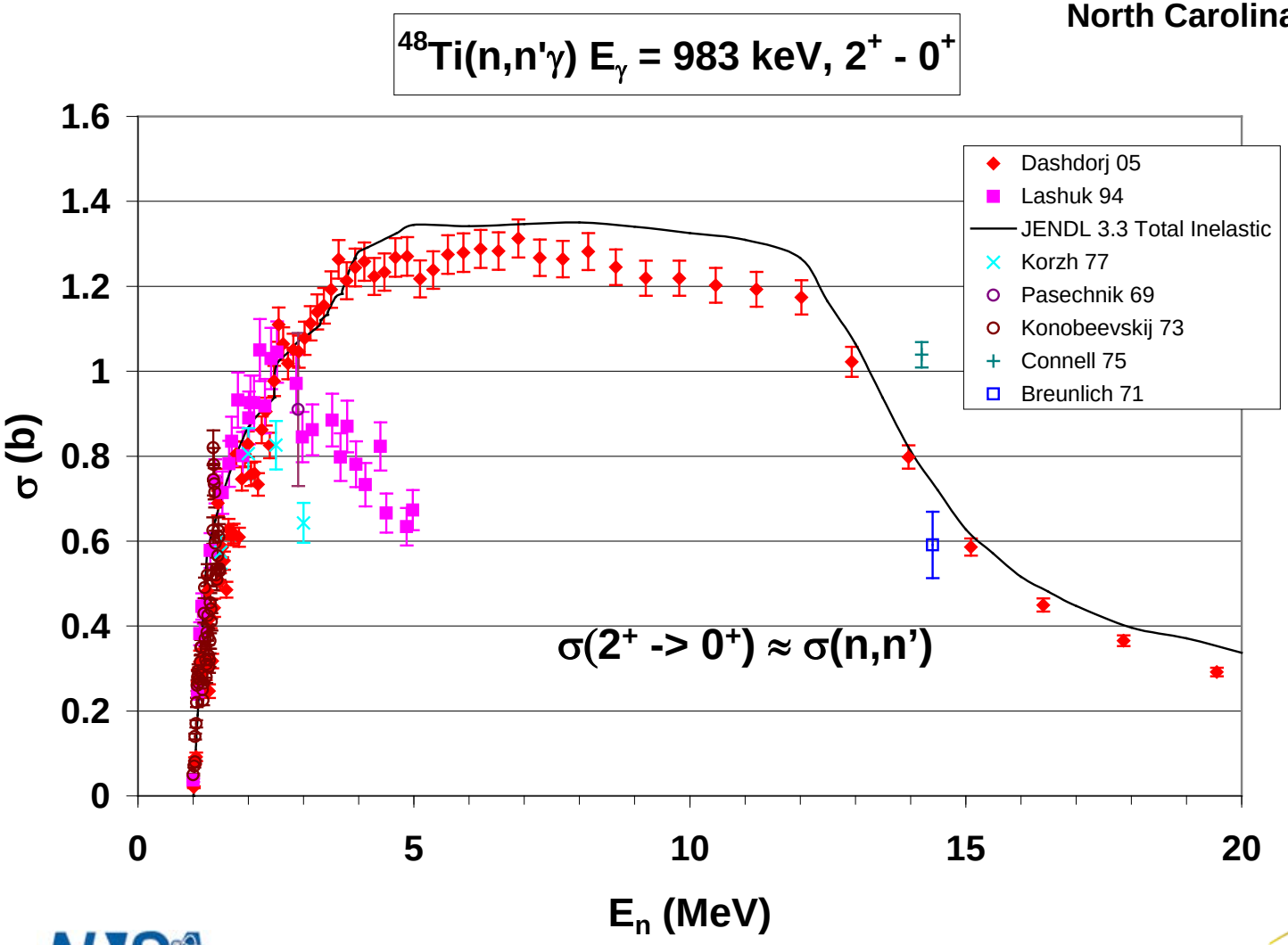
Sample	^{7}Li	^{48}Ti
E_n(MeV)	**1-8 MeV**	**4-15 MeV**
Eγ(keV)	**478**	**983**
Sigma(mb)	>100, 250 max	>600, 1200 max
E_n(MeV)		14-18 MeV
Eγ(keV)		160
Sigma(mb)		160-300
Source material	LiF UV optical windows	High-purity rolled metal foils
Issues	^{11}B(n,αγ)^{7}Li – boron shielding, isotopic composition determination	Angular anisotropy, (n,p) activation En>5 MeV – $t_{1/2}$=44 h, smaller cross section than Fe(n,p)

GEEL & LANSCE LiF(n,n'γ) 478 keV preliminary data compared to the CSISRS database (both n and γ)



Neutron Inelastic Scattering Cross Section for $^{48}Ti(n,n'\gamma)[74\%] + ^{49}Ti(n,2n\gamma)[5.4\%]$

D. Dashdorj, et al.
North Carolina State University

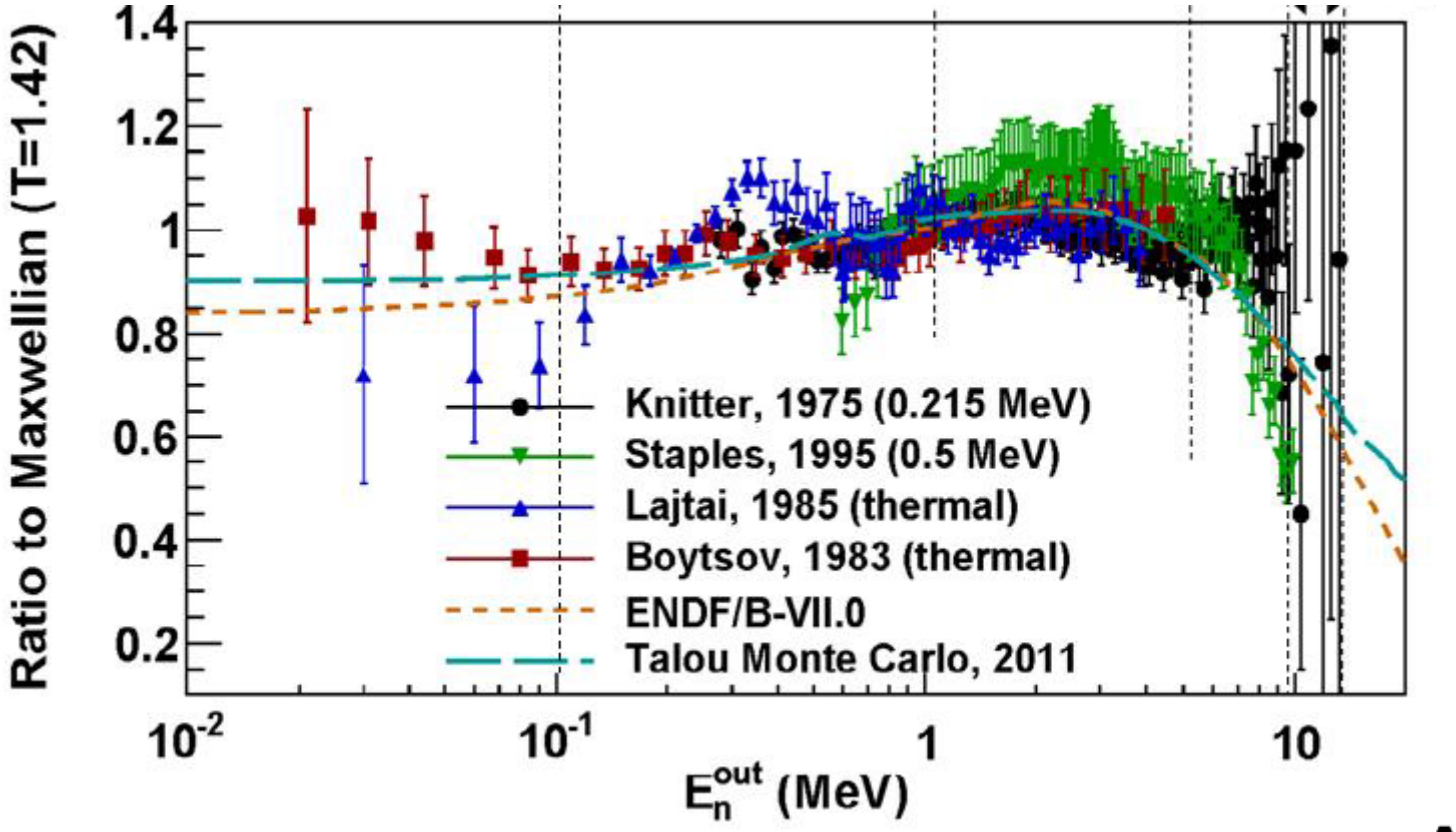


NNSA

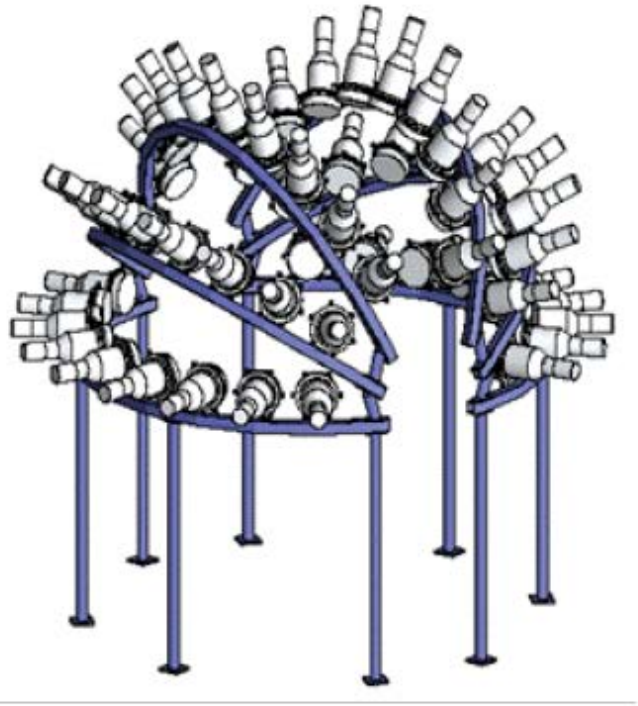
Los Alamos

Prompt fission neutron spectra measurements with the Chi-Nu arrays at LANSCE

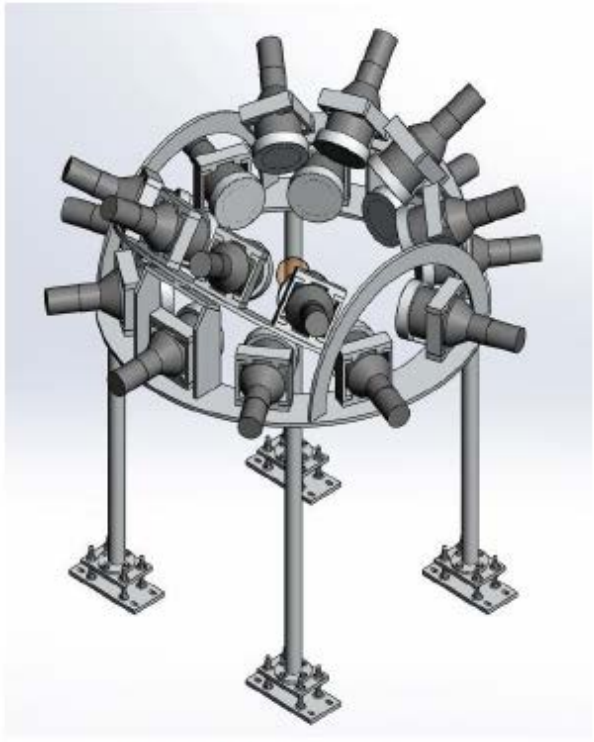
Prompt fission neutron emission spectra and evaluations/calculations



The Chi-Nu neutron detector arrays



54 Liquid scintillators – 1.0 m flight path

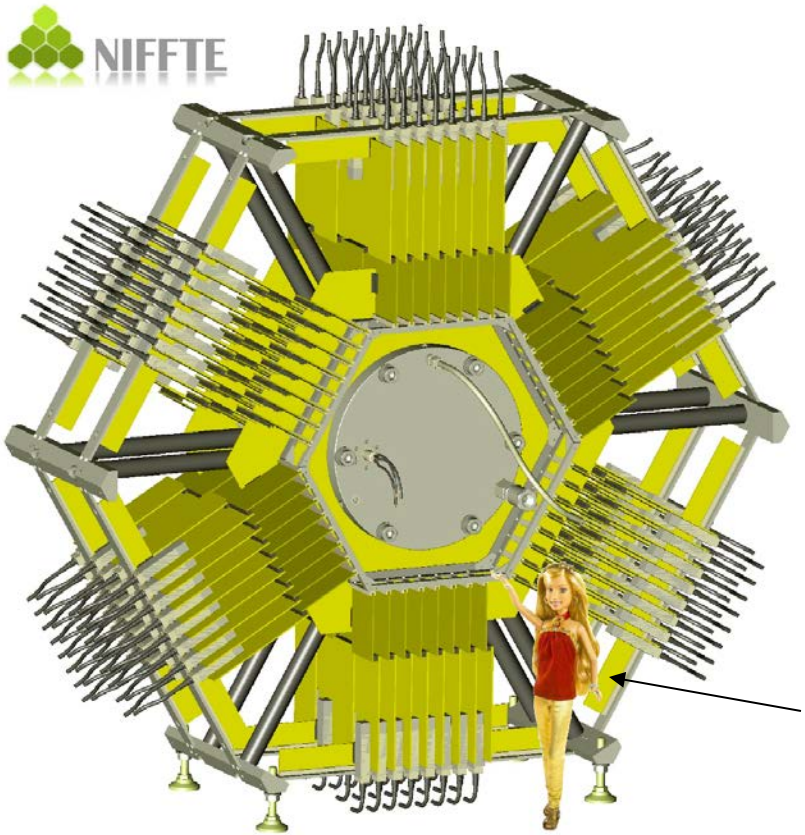


22 ^{6}Li-glass scintillators – 0.4 m flight path

Chi-Nu can be used with gamma-ray gating for inelastic neutron reaction studies

- Using Ge or higher efficiency good resolution gamma-ray detectors to tag events, for example, using the 2+ to 0+ gamma rays from inelastic scattering on an even-even nucleus
- The measured neutron spectrum provides information on the excitation energy of the nucleus and the energy and angle distributions of the emitted neutrons
- This was demonstrated previously with the FIGARO detector array at LANSCE

Time Projection Chamber (TPC)
a LANL-LLNL Project

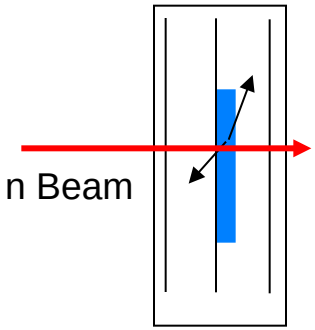


Barbie is shown for scale

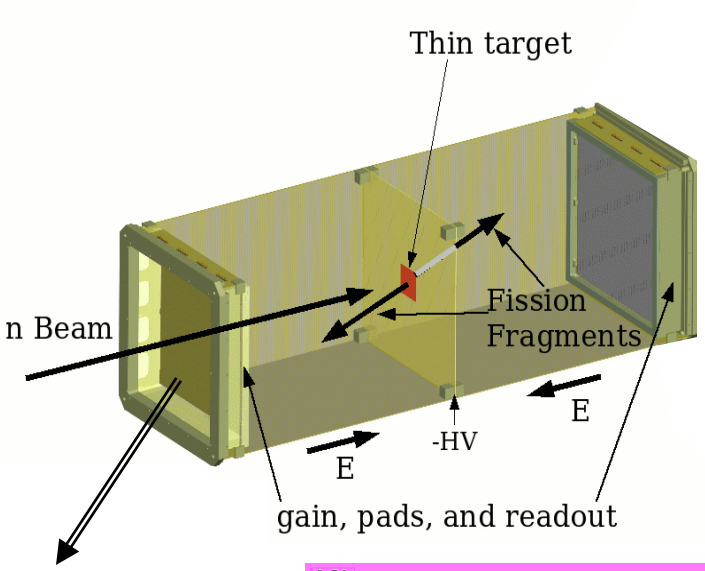
High-precision fission measurements are being performed with LLNL and Universities

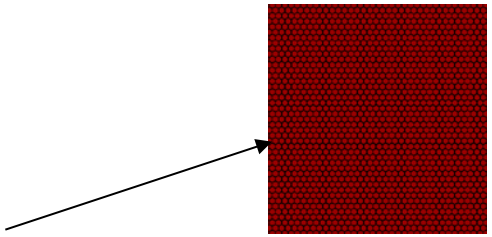
- High precision fission cross section measurements are needed for both Defense Programs as well as Nuclear Energy
- Past measurements with parallel plate ionization chambers have been limited by backgrounds from α particles.
- We are developing a new approach (with LLNL) for measuring fission cross sections that uses a Time Projection Chamber (TPC).

Ion Chamber

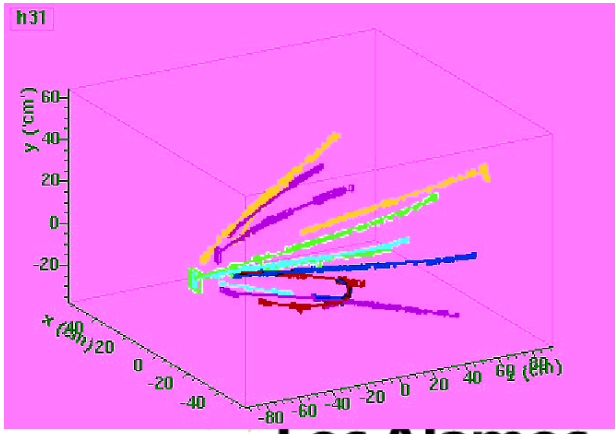


Time Projection Chamber



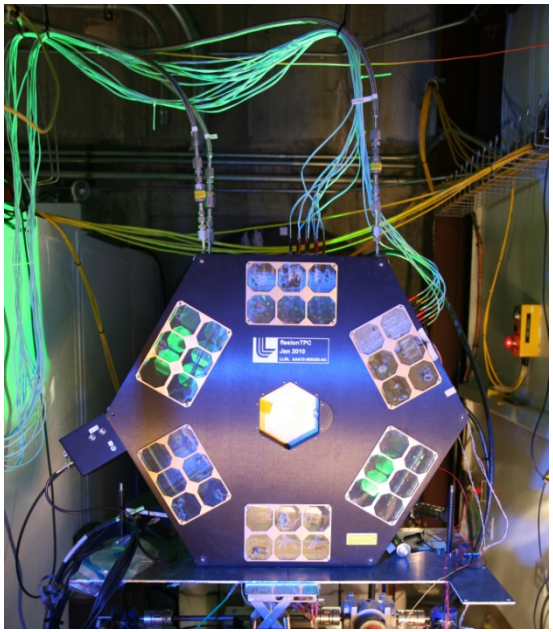


Anode is pixelated in XY plane and each pixel is sampled as a function of time (Z)

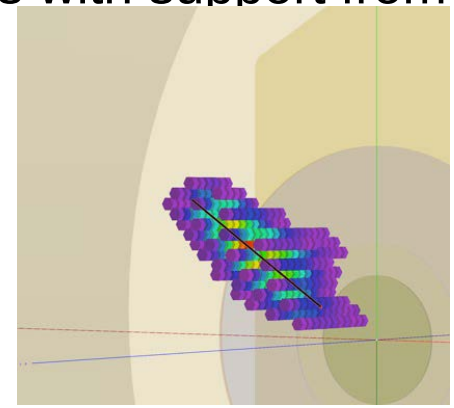


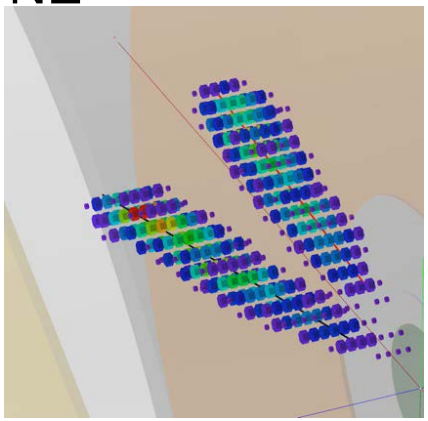
Time Projection Chamber will improve on past measurements

- TPC collection foil with pixilated collection plane
- TPC allows 3-D event track reconstruction
- TPC allows particle identification. Alphas are clearly differentiated from fission fragments
- Measurements will be made relative to ^{235}U and n-p standard cross sections
- This is significant effort with LLNL, INEL and 6 universities with support from NNSA and NE



Fission fragment track





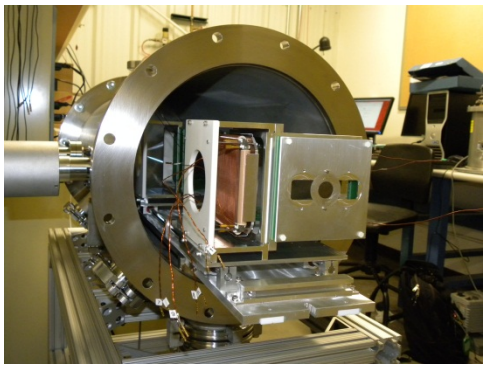
2 α-particle tracks

NNSA

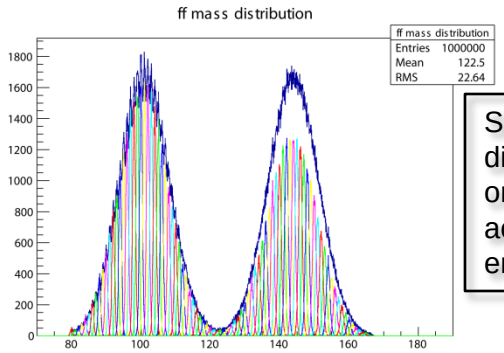
Los Alamos

SPectrometer for Ion DEtermination in Fission Research (SPIDER)

- New instrument for measuring independent fission yields
  - Fragment time-of-flight (TOF) spectrometer
    - Measures TOF and kinetic energy of both fragments in coincidence
    - Correlates fragment mass, charge and energy
  - Resolution
    - Mass: 1 amu for light fragments, 1.5 amu for heavy
    - Charge: 1 unit charge for light fragments (heavy fragment charge obtained from charge conservation)
    - Energy: 0.5-1.0%
  - Experiments at the Los Alamos Neutron Science Center (LANSCE)
    - Incident neutrons ranges from thermal to several hundred MeV (moderated and un-moderated spallation targets)
    - Neutron time-of-flight to measure incident neutron energy
- Timeline
  - Dual-arm spectrometer completed August 2013
  - Thermal fission yields for U-235 and Pu-239
    - Beam experiments Sept.-Nov. 2013
    - Preliminary results March 2014
    - Finalized mass yields August 2014
  - Fast-neutron induced fission yields for U-235 and Pu-239
    - Complete scaled-up of spectrometer August 2014
    - Beam experiments in 2014 and 2015
    - U-235 mass yields (E = 1 - 15 MeV) in 2015
    - Pu-239 mass yields (E = 1 - 15 MeV) in 2016



Timing detector assembly for the SPIDER spectrometer



Simulated mass distribution based on currently achieved TOF and energy resolution

Using Total Cross Section Measurements to Infer Neutron Capture Cross Sections Beyond the Reach of Direct (n,γ)

- Los Alamos Report - Paul Koehler, LA-UR-14-21466
- Determine average resonance spacing, D_0, and neutron strength function, S_0, values
- Use the Nuclear Statistical Model to calculate the capture cross section

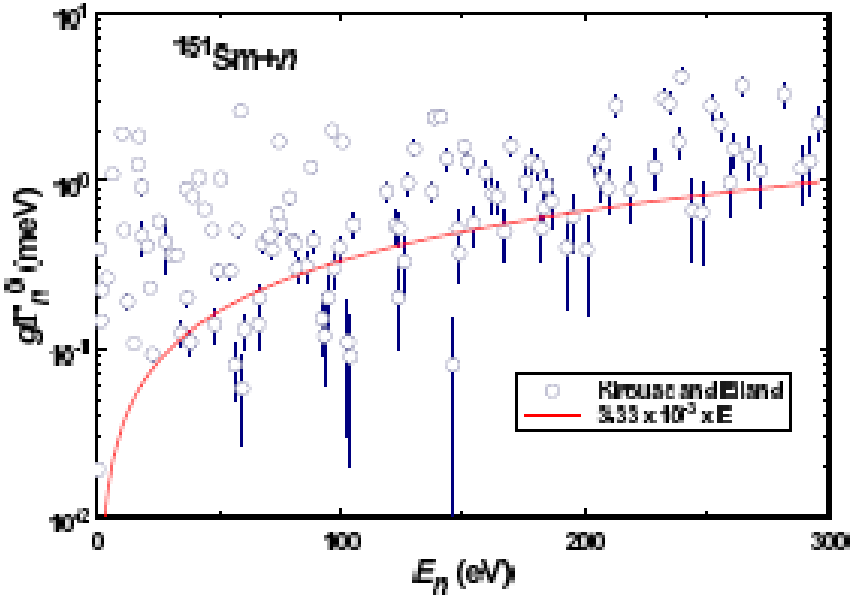


FIG. 1: Energy-reduced widths for ^{151}Sm neutron resonances from Ref. [3] (open blue circles). The red curve depicts the threshold used for obtaining corrected average resonance spacing (D_0) and neutron strength function (S_0) values. See text for details.

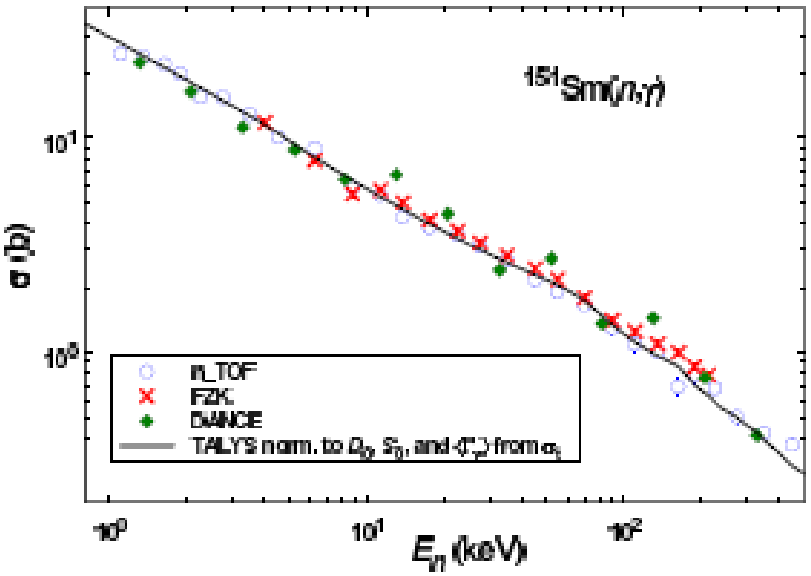


FIG. 2: ^{151}Sm(n,γ) cross section in the unresolved-resonance range. Symbols depict results from three different measurements [7–9], and the solid black curve is the cross section predicted by TALYS after adjustment to the average resonance parameters determined from the earlier ^{151}Sm+n total cross section measurement [3].

Plans to Develop Neutron Total Cross Section Measurements at LANSCE

- Use small (as low as 10 microgram) samples
  - Approx. 0.5 mm diameter
  - Tight collimation
- Good geometry total cross section measurements
  - Samples can be very radioactive and not affect the measurement (~ 10 meters to detector)
- Cross sections of interest for astrophysics and applications – 25 nuclei of interest are good candidates for measurement at LANSCE

Summary

- A wide variety of cross section measurements are performed at LANSCE
  - Neutron-induced gamma-ray measurements
    - » Gamma Ray reference cross sections for MeV neutrons
  - Neutron-induced fission measurements
- Operation of the accelerator at full duty cycle starts in October 2014
- All LANSCE Neutron production targets will continue operating
- The LANSCE Nuclear Science User Program had a record number of users in 2013 and continues in 2014
- New initiatives are planned to expand capabilities
  - Elastic and inelastic neutron scattering
  - Total cross sections for small and radioactive samples
    - » infer neutron capture cross sections

Thank you for your attention.